Comparison of the Production of Carbon Dioxide
Between the DES EGF and TVA
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Introduction

Buildings in downtown Nashville have two practical energy sources to provide space heating: steam and electricity. Electrical energy can be converted to space heating through the use of heat pumps or electric resistance devices. While steam can be generated locally with a fuel, such as natural gas, propane or even electricity, it can also be purchased from the Metro-Nashville District Energy System. Many comparisons have been made regarding the economics between using steam or electricity or self-generation or the purchasing of district steam. This article attempts to explain the difference in the environmental aspect of using electricity or steam to provide space heating and makes a comparison of the amounts of carbon dioxide produced to provide space heating to the downtown buildings.

Electricity Production and Transmission

The electricity consumed at an individual heat pump or resistance-heating element started its journey many miles away at an electric generation station. In order to deliver the electrical energy, more energy than required by the end-user device had to be produced by the generation station. This additional energy was lost in the transmission of the electricity through the overhead and buried transmission lines. These losses equate to approximately 10% of the total energy produced by the electric generation station - regardless of the fuel or energy source used. These losses imply that, for every 1.0 kiloWatt-hour consumed at a building, 1.10 kiloWatt-hours had to be produced from the electric generation station.

The sources of electricity for downtown Nashville are the various TVA plants located throughout the mid-south. Approximately 64% of the electricity produced by TVA utilizes coal. The remainder of the electricity is produced by nuclear energy (29%) or hydroelectric energy (7%). Therefore, of the 1.10 kiloWatt-hours production required to deliver 1.0 kiloWatt-hours to the end-user, approximately 0.7 kiloWatt-hours was produced using coal, 0.32 kiloWatt-hours was produced using nuclear energy and the balance (0.08 kiloWatt-hours) was produced by the hydro-electric stations.

Since hydroelectric energy production does not consume a fuel and is produced solely by the gravitational pull on surface waters, the conversion of the mechanical energy to electrical energy is nearly 100% efficient. The fission process produces waste heat and non-fissile by-products, thus the conversion efficiency of the nuclear energy into electrical energy at the generating station is less than 30%. Likewise, the typical Rankine Cycle coal-fired power plant converts approximately 30% of the available chemical energy in the coal into electricity. Therefore, in order to produce the 0.7 kiloWatt-hours, approximately 2.35 kiloWatt-hours (8,019 BTU) of chemical energy in the coal were required.

The hydroelectric generation does not require the chemical or nuclear consumption of a fuel, thus this source is not directly responsible for the production of any carbon dioxide or pollutants.

The production of electricity through nuclear fission does produce some radioactive wastes, but is also not directly responsible for the production of carbon dioxide or airborne pollutants. The combustion of coal typically produces many solid and airborne pollutants. Scrubbers, bag houses, filters and other pollution control equipment is required to meet the governmental regulations on the emissions of these pollutants. In addition, since the principle element in the available chemical energy in coal is carbon, the combustion of coal yields a considerable amount of carbon dioxide. In fact, approximately 2.46 pounds of carbon dioxide are produced per pound of coal burned.

Steam Production and Transmission

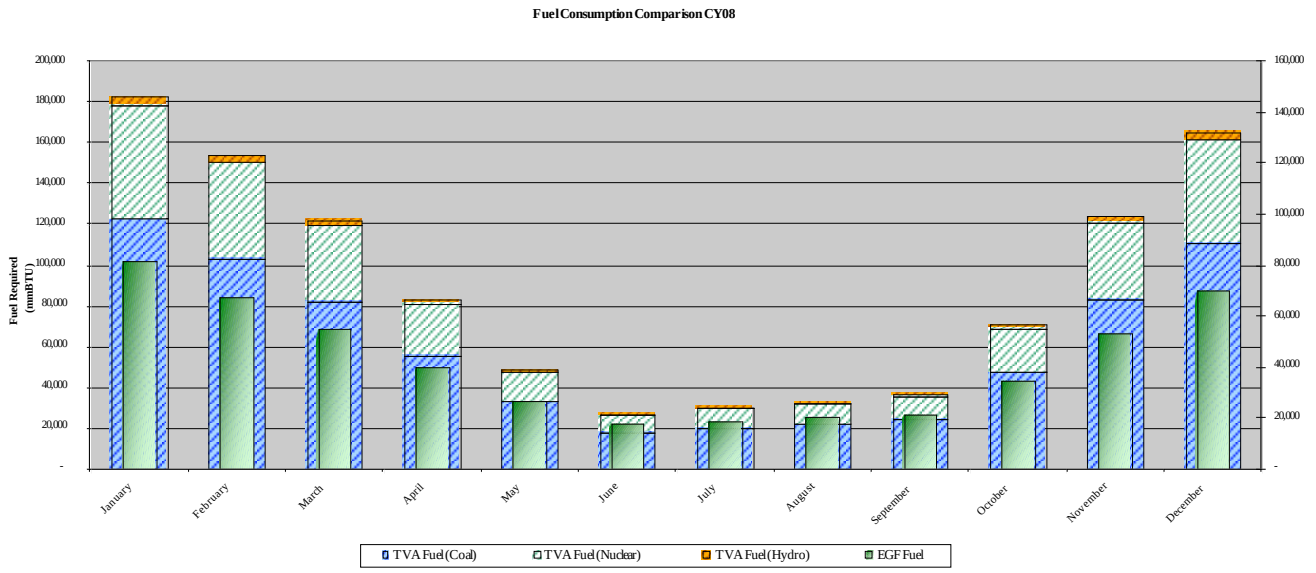
The steam used by a downtown building originated at the local Energy Generating Facility (EGF) located on Peabody Street in Nashville. This steam was produced by burning natural gas in one of their four package boilers. The transmission losses between the EGF and the various buildings vary but are typically 17% to 19%. These transmission losses imply that, for every pound of steam consumed by the customer, approximately 1.23 pounds of steam were produced. Each pound of steam contains approximately 1,022.1 BTU (0.3 kiloWatt-hours) of energy. Therefore, 3.34 pounds of steam must be consumed to equate to 1.0 kiloWatt-hour. With the transmission losses, 4.11 pounds of steam (1.23 kiloWatt-hours) were produced by the EGF for every pound consumed by the end-user. The difference in these values (0.23 kiloWatt-hours) is compared to the 0.1 kiloWatt-hours of transmission losses experienced by the distribution and consumption of electricity.

The boilers at the EGF have an historic annual average efficiency of 70.5% or 1.45 dekatherm per 1,000 pounds of steam produced. This efficiency is considerably greater than that of a Rankine Cycle coal-fired plant. In addition, no solid pollutants are produced by the combustion of natural gas. Very few regulated airborne pollutants are produced since the boilers utilize Low Nox burners. Other than these burners, there is no other pollution control equipment installed at the EGF, and the boilers remain in compliance with governmental regulations.

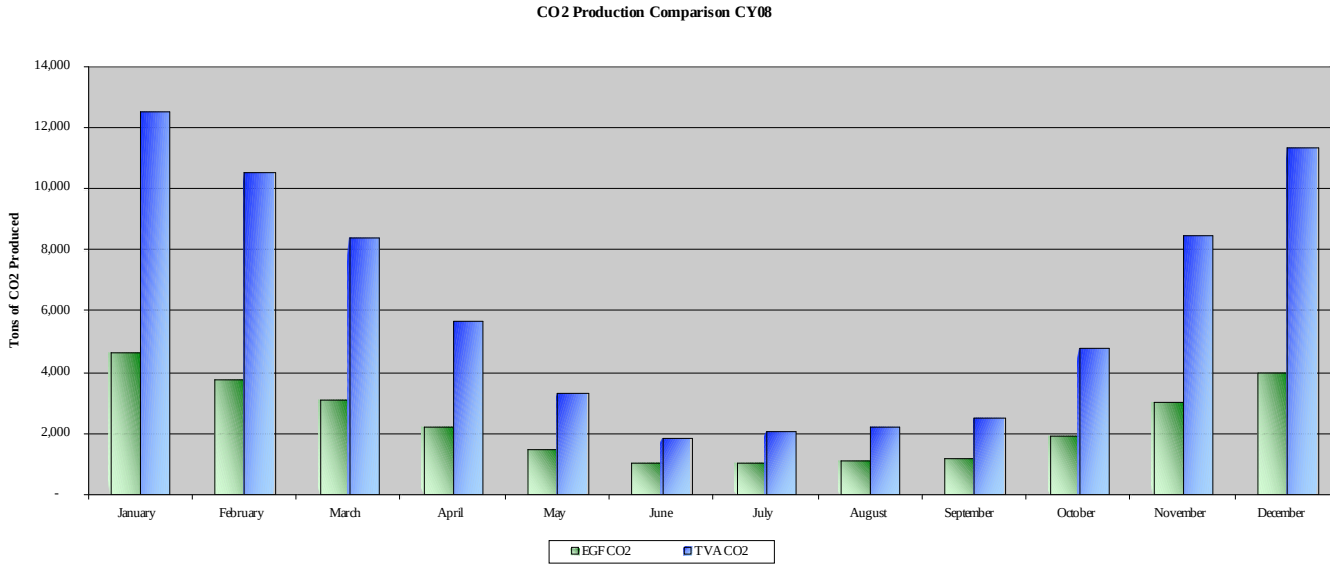
The chemical energy available in natural gas is derived from its hydrocarbon constituents. These compounds contain carbon, but also contain hydrogen, which has a considerably higher energy content per unit mass than carbon. The combustion of this composition yields 2.66 pounds of carbon dioxide per pound of fuel; however, fewer pounds of natural gas are required to release the same amount of energy as coal.

Carbon Dioxide Production

The following graph makes a comparison of the total energy required to produce and deliver the equivalent amounts of steam and electricity to the DES customer buildings for the calendar year 2008. The total steam sales for this period were 299,436 Mlbs of steam, which is equivalent to approximately 89,673,800 kiloWatt-hours of end-user consumption. In order to deliver this amount of energy, 507,859 mmBTU of natural gas was burned at the EGF. However, the combustion of 725,460 mmBTU of coal was required to produce and deliver the same energy to the customers.



Assuming that the heating values of natural gas and coal are 23,410 BTU per pound and 12,100 BTU per pound, respectively, approximately 21.7 million pounds of natural gas were required while 60 million pounds of coal were required to produce and deliver the same amount of energy to the end-user. The amount of coal consumed equates to only 64% of the total energy production required for the electrical generating stations. The amount of carbon dioxide produced by burning this amount of natural gas for the period was approximately 28,870 tons. The amount of carbon dioxide produced by burning coal would be approximately 73,870 tons. The following graph shows the monthly comparison of carbon dioxide production.



Conclusions

Space heating to buildings located in downtown Nashville can be provided by electricity or steam from the Metro DES. For the delivery of the equivalent amount of energy, the Metro DES has slightly greater transmission losses than the electric system. However, the production and delivery of steam from the Metro DES results in the production of fewer criteria pollutants and carbon dioxide than energy that is produced and delivered by the TVA Rankine Cycle coal-fired plants.